

# METHOD OF EVALUATING SUBSTATION RECORDS OF HAIL AND THUNDER

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## ABSTRACT

Cooperative substation records of hail and thunder incidences have been used as a source of data to develop more accurate and detailed average patterns of these phenomena. Since the accuracy and completeness of records by volunteer observers are generally considered questionable, a method of determining accurate substation records of thunder and hail was devised. The evaluation method relies strongly on comparisons of substation data with those from nearby first-order stations. The number of stations with accurate hail records was found to be greater than the number with accurate thunder records. Reliable records of both events in Illinois and surrounding States have provided very useful information.

## 1. INTRODUCTION

The U.S. Weather Bureau first-order stations are a source of accurate climatological data on days with hail and thunderstorms. These data have been used to analyze the point frequencies of these events [1], and to determine areal mean patterns [2].

However, first-order stations are too sparsely located to sample, and thus adequately describe, many of the significant areal variations existing in mean thunder and hail patterns in the United States. This is particularly true in areas with significant topographic features such as hills, mountains, and large lakes. Research in Illinois has shown that even in featureless flatlands, sharp areal variations in hail-day frequencies can occur across 50-mi. distances [3]. Information about such variations has practical value to agricultural and insurance interests, and is of general interest to atmospheric scientists.

The many cooperative substations of the U.S. Weather Bureau are the only source of climatological data that could enable the development of more detailed and accurate areal patterns of hail-day and thunder-day frequencies [4]. Many atmospheric scientists have not attempted to use these substation records, other than for temperature or rainfall data, believing that the volunteer observers were not reliable reporters of other weather conditions.

A desire to obtain greater detail in the average thunder and hail patterns in Illinois led to a careful investigation of the quality of the substation records of hail [3] and thunder [4]. The weather records of 51 Illinois substations with relatively long records, 60 yr. or more, were available on punch cards [5], and machine-produced listings of thunder and hail days by years allowed a rapid

examination of their general quality. These listed values plus those from 60 other substations with shorter records were compared with those for 11 first-order stations in and near Illinois. Upon comparison, it was obvious that some of the substations had periods of hail and thunder records with values quite comparable with those of the nearby first-order stations. Further examination of these apparently "good" periods of record revealed that they were often associated with a period of observation by a particular volunteer observer. These good periods of record varied from only a few years at some stations to as many as 50 yr. at others. Frequently two or three good periods of record were found in different portions of the 60-yr. record of the substation. Thus, the possibility of assessing quality hail and thunder data in substation records had been determined.

## 2. METHODOLOGY

The first step in the evaluation procedure for a substation was to compute and list the number of hail and thunder occurrences for each year, and to mark all the observer changes on this list. This list was then compared with the listings for the one or two nearest first-order stations, and this comparison yielded periods of record at the substation when apparently "good" records of hail or thunder were made. In every instance, records that were here classified as not good, and thus eliminated from further analysis, were a result of too few reports of hail or thunder.

Since these good records were frequently for short, 10- to 20-yr., discrete periods of time during the 1901-63 period, the data were adjusted to allow for any temporal

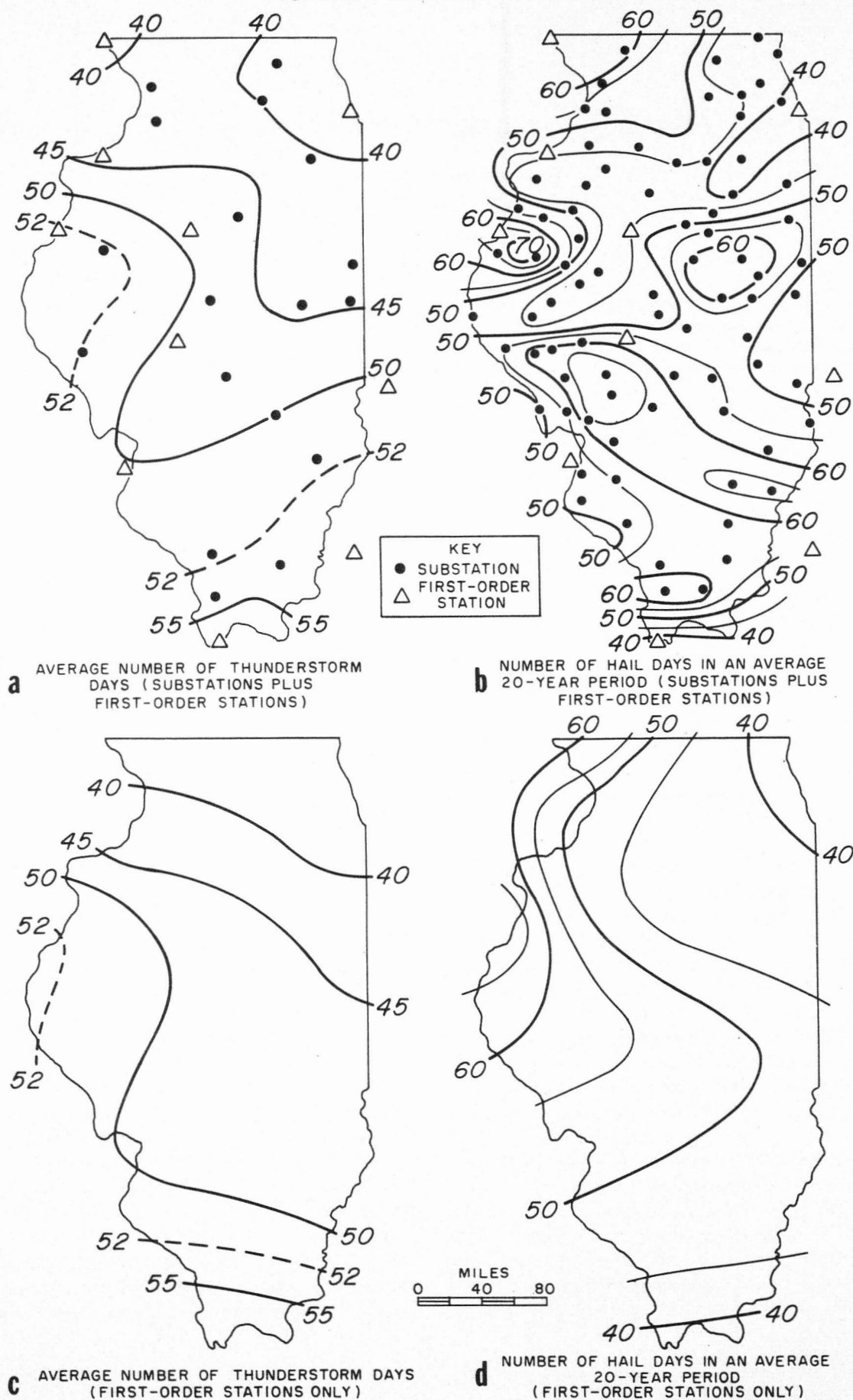


FIGURE 1.—Average thunderstorm-day and hail-day patterns for Illinois.

variations in thunder and hail incidences. It should be remembered that the desired results from these substations were monthly, seasonal, and annual averages of hail and thunder occurrences that would be comparable with long-term averages of the first-order stations. Examination of the individual first-order station data had revealed considerable temporal variability in the occurrence of hail and thunder such that the numbers of hailstorms in some 10-yr. periods were as much as 60 percent greater or less than the long-term average [3]. The temporal variation of these events is sufficiently great that accurate data for any particular 10- or 20-yr. period may provide a point average that is considerably above or below the true long-term average for that point.

To obtain values to adjust for these sampling vagaries, 10-yr. running totals of thunder and hail values were computed for the first-order stations, and these values were expressed as percentages of the long-term means. For instance, calculations for Moline, Ill., revealed that the number of hail days in the 1906–15 period represented 119 percent of the average, whereas the 1916–25 total was 96 percent of the average. For each 10-yr. period isopercentile State maps based on data from all first-order stations in and around Illinois were prepared.

Regional interpolation of these isopercentile maps furnished the adjustment factors for the good periods of record at the substations. For example, if a substation had an apparently good period of hail records for 1926–35, the station's location was plotted on the 1926–35 isopercentile map and a percentage value was interpolated for it. All the 1926–35 monthly totals of hail days at the substation were then multiplied by this adjustment percentage, and the resulting numbers were those used in calculating the final averages. Each good period of data was adjusted according to the isopercentile value that applied to that specific period.

Once the "good" records at a substation had been adjusted, the values were totaled and monthly averages were computed. Monthly maps of the averages for the first-order stations and the substations were plotted. Isopleth analyses of these monthly maps usually revealed that certain substation values were considerably larger or smaller than the values of surrounding stations. After all monthly maps had been so analyzed, a list was prepared indicating the substations with apparently unrealistic or erroneous monthly values. If a substation had these erroneous values in two or more months, the station data were considered inaccurate and deleted from further analysis.

The final phase in the process of evaluating the substation data was also based on the monthly averages. At each station the values of the four months with the highest averages were ranked, and the results plotted on a map. This map revealed regions in which most stations had a similar rank sequences such as (1) June, (2) May, (3) July, and (4) April. Stations with rank sequences

significantly different from those at surrounding stations, particularly for the first and second rank values, were eliminated from further analysis as having unreliable data. The periods of "good" record remaining after this final stage of evaluation were considered accurate and acceptable for use in the final analysis of hail and thunder frequencies. In Illinois, 85 substations were found to have quality hail records for 15-yr. or longer periods, and 18 substations had 15-yr. or longer good thunderstorm records.

### 3. RESULTS

The resulting patterns of average thunder days and hail days in Illinois are portrayed in figure 1a and 1b, respectively. Similar patterns based solely on the first-order station data appear in figure 1c and 1d. Comparison of the maps reveals the detail added by the substation data. On the more detailed hail map (fig. 1b), the substation data are shown to have been primarily responsible for detecting the existence of areas of relatively high incidence in southeastern, eastern, and extreme southern Illinois, as well as in a narrow trough extending from western Illinois toward Lake Michigan. The causes of the variations in the detailed hail and thunderstorm patterns in Illinois have been studied by Huff [6]. He found that the areal distributions of mean maximum temperatures, mean noon dew-point temperatures, normal rainfall, and the number of surface fronts together explained between 56 and 90 percent of the variations in the hail and thunderstorm patterns. These findings strongly support the validity of the detailed patterns, and reveal that these patterns were largely determined by macroscale weather conditions.

Similar analysis of hail-days in Iowa and Missouri has been performed with this evaluation technique [7], and currently the hail and thunder data in Indiana, Michigan, and Wisconsin are being evaluated in a study of the effects of Lake Michigan on severe weather [8].

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